The potential for real time posture detection through garment-integrated electrostatic sensors

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ABSTRACT

On body devices, and the busses that interconnect them, present a unique opportunity for on body sensing technologies. By gathering electrostatic data about their user and their environment, it is possible to model the user's electrostatic interaction with their environment. Through these models an intuitive understanding of the user's electrostatic ecology is developed allowing the ability to draw meaningful inference about posture and relative body orientation.

INTRODUCTION

New and previously overlooked ways of applying existing sensor technology are required in order to advance the state of the art in on body sensing. Sensors that have no analogue in the human sensorium are often unintuitive and slightly alien and as a result are often under-researched techniques and an ideal source of new techniques. One of the least explored, and most promising, of these areas is electrostatic sensors.

Unlike the magnetic dipoles, electrically charged objects can be monopoles; electrically charged objects are able to take on either a positive or negative charge and do not have to be paired to a counterpart of opposing charge. As a result objects, even otherwise electrically insulated, are free to take on either a positive or negative charge in response to their environment. The reader will likely remember a popular demonstration of Coulomb's Law where a metal covered pith ball, suspended by a thread inside a glass chamber, is moved by first giving the ball a negative electrical charge and then using a positively charged object outside of the glass chamber to move the ball through electrostatic repulsion. This demonstration illustrated that electrostatic effects operate through electrical insulators.

All modern electronics expect some degree of electrostatic interaction with their environment, reflected in operational tolerances for parameters such as input and load capacitances. Garment integrated systems are especially well positioned to take advantage of these design constraints to implement a new class of on body, electrostatic sensors. Distributed as they are throughout the user's immediate environment the collection of electrostatic data from on body devices describes the user's current electrostatic ecology. Two distinct types of measurements should be possible using electrostatic techniques; either direct measurement of the bend angle of the limbs and the pose and orientation of the limbs relative to the trunk. As electrostatic sensing techniques only require the use of garment integrated conductive paths they are particularly well suited for garment integration.

GARMENT INTEGRATED ELECTROSTATIC SENSORS

Employing real time knowledge of the user's electrostatic ecology presents a host of nontrivial problems; first in accurately gathering the information, and then later in imparting meaning from them. While previous work has been done looking at electrostatic sensing on and near the body [1, 2] they have shown the problem to be a fertile field for future work. Currently the problems facing on body devices require assembling of systems which work with noisy signals within dynamic and poorly understood environments. Compounding these already significant problems on body devices inherently operate in the most expensive non military HCI real estate. Fortunately the potential benefits derived from knowledge of the users electrostatic ecology is in proportion to these challenges.

The first benefit is derived from the fact that garment and apparel integrated devices are physically distributed throughout the user's immediate environment. By making each individual on body device capable of reporting the current electrostatic potential for its location, the collection of devices reports a discrete electrostatic image of the user's environment.

The second advantage is that the wires that carry power and data throughout the garment can also be used as sensors distributed over the body. Busses used as sensors can thus provide a measure of the electrostatic potential across the large areas of the body spanned by the buss. Taken together with a set of discreet measurements of electrostatic potential these techniques promise to image the electrostatic environment of the user without needing to add additional devices within the prohibitively expensive real estate on the body.

Finally implementing garment integrated busses already require routing conductive material around the body in a manner that does not compromise the garment. As a result as implementation issues are overcome in using the power and data busses as sensors the potential also exists to add new conductive paths specifically to act as sensors. Since these sensors would be added to places where no devices or busses were previously located, they would occupy new real-estate on the body for use as sensors.

MINING THE BUSSES FOR ELECTROSTATIC DATA

If the hardware used on garment integrated busses is designed with the ability to record current flow and transition times during buss switching events the buss can double as a capacitive sensor. While a detailed analysis of how such a sensor could work is exactly the work this position paper hopes to encourage, a first order is desirable.

Capacitance is usually defined as the total electric charge placed on the object divided by the potential of the object *($C = Q/V$)*. Recall that the current flow through a capacitive element *($I = C(dV/dt)$* is given by effective capacitance multiplied by the time derivative of the voltage. From this we see that capacitance is approximated by the current multiplied by switching time divided by the voltage *($C = I\ (dt)/dV$)*, in effect giving *(Q/V)*. The current flowing into or out of the buss *(I)* is easily monitored with existing techniques[3]. So by monitoring the current *(I)*, and the transition times *(dt)* to switch the buss over a known voltage *(dV)* we have a simple measure of the capacitance of the buss (C) and the charge on the buss *(Q)*.

Electrostatic sensors can either be passive or active. Both passive and active sensors provide a single signal that is a function simultaneously reflecting both changes in posture and environment. Passive sensors only measure changes in the naturally occurring charge on the body whereas active sensors will include charge inducing elements.

Conductive areas in the garment (e.g. power and data busses or explicitly added sensor strips) also have the potential to be used as charge inducing areas to enable active electrostatic sensors. Active sensors should be far less affected by changes in the environment. To further aid sensor discrimination active sensors can be driven and checked within at a unique target frequency band. Mimicking common industrial techniques [3] like real time detection of shoulder orientation use two sets of conductive strips placed on the body trunk and arm to act as sensors. One set of buss lines or conductive strips would be actively driven at the target frequency and their complement would be polled for charge appearing at the target frequency.

DETECTING POSTURE

Garment integration of electrostatic sensors promises the ability to produce a discrete array of body spanning sensors, independent of environmental sensing infrastructure such as cameras or invasive body instrumentation. Previously on and near body systems have demonstrated using electrostatic interaction with the body to infer hand position [4-6]. Under ideal conditions a single wire running down a limb can already measure bend angle [3]. Using a collection of such wires under ideal circumstances we can already reasonably gather a large quantity of information about the body. Fortunately there are a number of special cases in posture detection which should give insight into the user's current pose and aid in the task of inferring posture from knowledge of the user's electrostatic state in un-ideal or poorly understood environments.

Points near the trunk are promising since they are shielded from the environment and are areas of minimal range of motion. Being shielded means data collected will be much less sensitive to environmental noise. The minimal instrumentation through the armpits, and the upper inseam of the trousers should be able to gauge the rough orientation and trunk to limb distance.

Since the body is a collection of interconnected joints, by looking at a collection of crude orientation information for each segment we can construct a more accurate overall picture of the current body's posture [7]. Where these techniques prove inadequate more sensors can be explicitly added to the garment to aide detection of specific postures. For example by driving a conductor running across the front of one knee and then checking electrostatic potential a conductor on the back of the other knee can detect if the knees appear crossed. Through similar means we could check to see if the arms were crossed. By iteratively driving and checking sensors in the forearm and trunk a crude estimate for the arms orientation position is possible.

CONCLUSION

Even gross detection of posture is of enormous potential use in user interface design. Even the crudest postural knowledge such as detecting if the user's arms are crossed provides insight into its user's current emotional state. Electrostatic sensors are a promising non-invasive on body sensing technology, ideally suited for garment integration in areas of otherwise prohibitively expensive user interface real estate.

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